chirality, allowing the momentum and the spin (or pseudo-spin) either parallel or antiparallel (called left or right handed). By applying a magnetic field, electrons are transferred from one Weyl point to the other with the opposite chirality, modifying the electron population and thus breaking the number conservation of Weyl fermions with a given chirality. This phenomenon, predicted in 1969, is called chiral anomaly[6,7]. As a consequence, a negative magnetoresistance is observed when an external magnetic field is applied parallel to the charge current direction (Fig. 2) independent of the crystal direction. The magnetic field, direction and strength, allows for the tuning of the position and the number of Weyl points in the magnetic Heusler compound.

Hirschberger and co-workers also report a strong dependence of the Seebeck effect — a voltage generated by a temperature gradient — as a function of the applied magnetic field. This observation is consistent with the anisotropic nature of the Weyl node formation, and constitutes further proof of the tunability of the GdPtBi band structure by a magnetic field.

The inverted band structure of GdPtBi is the precondition where the magnetic field can induce the Weyl point by the Zeeman splitting. Therefore, as proposed by Hirschberger and colleagues, this mechanism can be generalized to many other Heusler topological insulators and HgTe with the same band topology. Surprisingly, the antiferromagnetic ordering of GdPtBi was not found to play a significant role. This very broad conclusion might require further examinations, yet the very soft magnetic moments of GdPtBi may be tuned by the external magnetic field, and the varied strong exchange field manipulates the electronic bands, giving rise to Weyl points and related exotic phenomena. An investigation of several magnetic and nonmagnetic Heusler compounds with different rare earth elements could be very useful to further clarify the physical mechanism involved.

There are a large number of tunable half-Heusler alloys, which may lead to a substantial increase in the number of Weyl semimetals available. In addition, the finding by Hirschberger and co-workers builds a bridge between two so far unconnected areas: Weyl semimetals and topological insulators on one side and spintronics and spincaloritronics on the other. Other materials with touching bands, high spin–orbit coupling, high magnetic ordering temperatures and possibly soft magnetic behaviours will probably enable room temperature effects. Quantum field theory may thus become the foundation of entirely new families of electronic devices based on spin-orbitronics that relies on spin–orbit coupling, ultra-fast electrons, titanic magneto-resistance effects and spin-caloritronics. ❐

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AMORPHOUS SOLIDS

Rayleigh scattering revisited

Scaling of the phonon damping with the wavevector in glasses is found to be different from the traditionally assumed Rayleigh scattering, and related to surprising, long-range correlations in the local elasticity matrix.

Jeppe C. Dyre

The scattering of waves by small impurities (compared to the wavelength) is known as Rayleigh scattering, named after the British physicist who in 1871 first described this phenomenon quantitatively[1]. Rayleigh scattering is a universal mechanism applicable to several contexts, from light scattering (damping of signals in optical fibres) to sound waves in solids[2] and quantum-mechanical wavefunctions of electrons in disordered solids[3]. Mathematically, Rayleigh scattering predicts a mean free path of the wave that varies with wavelength λ, proportional to $1/\lambda^4$. According to this formula, blue light with a wavelength half that of red light is scattered 16 times more; sunlight is scattered by minute dust particles, making the sky appear blue.

A sound wave travels virtually without damping in a perfect crystal. However, in a non-perfect solid (such as crystals with defects or impurities or, more generally, amorphous solids) one expects sound waves to be damped by Rayleigh scattering. This textbook 'knowledge'[4] is now being questioned by Anaël Lemaître and colleagues in *Nature Materials*[5]. They discuss the existence of novel long-ranged correlations in amorphous solids. Although a full theory has yet to be constructed, the authors' arguments call for the current physical model of amorphous solids to be revisited.

Lemaître and collaborators present results from extensive computer simulations of a soft-sphere mixture in two dimensions. Solid configurations were obtained by quenching equilibrium liquid-state configurations to absolute zero temperature, a state of perfect mechanical equilibrium in which the force on each particle is zero. Sound waves were then studied by numerically solving Newton's equations of motion for the solid's constituent particles, subject to the initial condition of a perfect transverse or longitudinal sound wave. The data show that the damping coefficient Γ does not follow the Rayleigh prediction $\Gamma \propto 1/\lambda^4$ but has an extra logarithmic term.

The logarithmic enhancement of sound-wave scattering is supported by evidence for a breakdown of the Rayleigh scattering law from simulations in three dimensions[6], as well as by revisiting experimental data for the damping of sound waves in various glasses (glycerol, sorbitol, and silica). The standard assumption that an amorphous solid scatters sound waves by random impurities reflecting the local elastic disorder seems difficult to uphold.

Why does the Rayleigh scattering law break down in amorphous solids? It is the assumption of randomness that is problematic. It was recently shown that long-range correlations in the local stress field are present in amorphous solids. These correlations decay with distance r

(Fig. 1), following the formulae $1/r^2$ in two dimensions and $1/r^3$ in three dimensions[7,8]. The authors demonstrate that long-range correlations are also present in the local elasticity matrix (which determines the stress change following externally imposed atom displacements), and these correlations have the very same distance dependence as the stress correlations (Fig. 1). Combined with previous theoretical work[9], this surprising observation explains the logarithmic enhancement of Rayleigh scattering. What causes the long-ranged local elasticity matrix correlations? Lemaître and co-workers argue that these arise because the local pressure and pair-level stiffness correlate strongly in their variation throughout the solid, reflecting the fundamental fact that despite its disorder an amorphous solid consists of particles subject to the same microscopic interactions throughout the solid.

An open question is whether the present findings apply for mixtures of many different types of particles, in which case the Hamiltonian is complex[10]. More generally, the paper gives an interesting twist to the long-standing discussion about what kind of randomness characterizes a glass. An important question for understanding the glass transition and the glassy phase[11,12] is to what extent a glass is like a spin glass with random parameters in the Hamiltonian. In other words: is a glass's disorder properly reflected by assuming randomness[13]? It appears that an answer has been given; glasses and most amorphous solids cannot be regarded merely as random solids. ❐

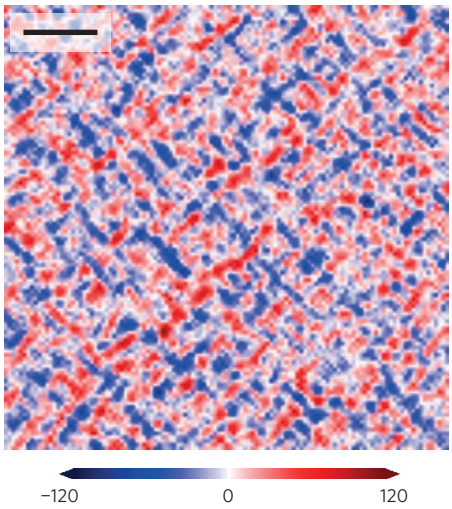

Figure 1 | Computer simulation of a stress field in an amorphous two-dimensional solid. Stress correlations extend over relatively large scales. Similar correlations have now been identified for the local elasticity matrix of amorphous solids, implying a breakdown of the Rayleigh scattering law for sound waves. (Scale bar equals 10 atoms.) Figure reproduced from ref. 5, Nature Publishing Group.

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COLLOIDAL CRYSTALS

Stresses come to light

Confocal microscopy and computational analysis, now used for measuring microscale stresses in colloidal crystals, could be developed for investigation of amorphous materials, crystal melting, and mechanical properties of tissues.

Mark Bowick and Paul Chaikin

The beauty of crystals, our fascination with their symmetries and our knowledge of their internal structure come from the almost perfect periodic order of their elements. The interference of X-rays scattered from periodic planes of atoms has allowed crystallographers to unravel the intricacies of their molecular configurations and led countless generations of students to learn how to think in reciprocal space. Many of the most useful (or harmful) properties of materials, however, emerge from their defects. Strength, ductility, brittleness, diffusion and other mechanical properties are controlled by the presence and motion of vacancies, interstitials, dislocations, and grain boundaries, which break the perfect order. The inability to image atomic scale defects in bulk necessitates the use of macroscopic model systems for analysis of such elements. The father of X-ray crystallography, Sir William Lawrence Bragg, for instance studied floating monodispersed bubbles assembled into rafts, which readily display dislocations, vacancies and grain boundaries[1,2] (Fig. 1a). The system is inherently two-dimensional, though, and does not reveal the forces and stresses resulting from the defects. Using a colloidal model system, Itai Cohen and colleagues now report in *Nature Materials* a sophisticated technique to measure stresses arising at crystalline defects[3], enabling further understanding of how such features are linked to material mechanical behaviour.

Cohen and co-authors perform these measurements on 'hard sphere' colloids that interact only through collisions. The particles' refractive index is matched to the suspending fluid, and the particles are dyed, which enables a confocal microscope to image the colloids' positions deep into the crystal bulk. Measuring the collisions from all neighbours yields the anisotropic forces on a particle, and hence the pressure and stresses. While the idea is straightforward, the implementation is not. Collision and forces must be defined and particle positions measured with utmost accuracy. With their technique (named SALSA: stress assessment from local structural anisotropy), Cohen and co-authors find that the hard sphere system can be qualitatively described by linear elastic theory, but that there are important nonlinear stress components, which may help explain the attraction of vacancies (leading to void formation) and the softening of dislocation cores. While topological and point defects have provided a vigorous formalism for